

WHAT IS CLAIMED IS:

1 1. A power converter comprising:
2 a switch that electrically couples or decouples a load to or from a power
3 source; and
4 a switch controller coupled to the switch for controlling on-times and off-
5 times of the switch, the switch controller including:
6 an event detection module for generating a digital error signal, the
7 digital error signal being generated at a switching
8 frequency of the switch and indicating a voltage delivered
9 to the load in a first switching cycle of the switch in
10 relation to a reference voltage to be delivered to the load;
11 and
12 a pulse generator coupled to the event detection module for
13 generating a pulse signal that determines the on-time and
14 off-time of the switch for a second switching cycle
15 subsequent to the first switching cycle based upon the
16 digital error signal.

1 2. The power converter of claim 1, wherein the power converter is a primary
2 side sensing flyback power converter and includes a transformer coupled between the
3 switch and the load and having a primary winding coupled to the switch, a secondary

4 winding coupled to the load, and an auxiliary winding coupled to the switch controller,
5 the switch controller determining:

6 a knee voltage timing, the knee voltage timing indicating the timing when
7 a sensed voltage at the auxiliary winding equals a knee voltage at
8 which a current through the secondary winding of the transformer
9 falls to substantially zero; and

10 a reference voltage timing, the reference voltage timing indicating the
11 timing when the sensed voltage at the auxiliary winding equals the
12 reference voltage.

1 3. The power converter of claim 2, wherein the event detection module:
2 determines a gap quantifying a difference between the knee voltage
3 timing and the reference voltage timing; and
4 subtracts the gap from a predetermined sample time offset to generate the
5 digital error signal, the sample time offset corresponding to a
6 predetermined time difference between a sampling timing of the
7 sensed voltage and the knee voltage timing.

1 4. The power converter of claim 3, wherein the knee voltage is lower than
2 the reference voltage by a forward voltage drop of a diode coupled between the
3 secondary winding and the load as reflected on the auxiliary winding, the forward voltage
4 drop corresponding to an amount of current that flows through the diode during the
5 sampling time offset.

1 5. The power converter of claim 3, wherein the pulse generator generates the
2 pulse signal to decrease the on-time of the switch in the second switching cycle when the
3 digital error signal has a positive value and to increase the on-time of the switch in the
4 second switching cycle when the digital error signal has a negative value.

1 6. The power converter of claim 3, wherein the pulse generates the pulse
2 signal to maintain the on-time of the switch in the second switching cycle to be same as
3 the on-time of the switch in the first switching cycle when the digital error signal has a
4 value of zero.

1 7. The power converter of claim 3, wherein the switch controller further
2 includes:

3 a knee voltage comparator comparing the sensed voltage to the knee
4 voltage to generate a knee voltage comparator signal that is high
5 when the sensed voltage is higher than the knee voltage and low
6 when the sensed voltage is lower than the knee voltage, the event
7 detection module determining the knee voltage timing by
8 determining a transition timing of the knee voltage comparator
9 signal from high to low; and

10 a reference voltage comparator comparing the sensed voltage to the
11 reference voltage to generate a reference voltage comparator signal
12 that is high when the sensed voltage is higher than the reference
13 voltage and low when the sensed voltage is lower than the

14 reference voltage, the event detection module determining the
15 reference voltage timing by determining a transition timing of the
16 reference voltage comparator signal from high to low.

1 8. The power converter of claim 7, wherein the switch controller further
2 includes a zero voltage comparator comparing the sensed voltage to a zero voltage
3 reference voltage to generate a zero voltage comparator signal that is high when the
4 sensed voltage is higher than the zero voltage reference voltage and low when the sensed
5 voltage is lower than the zero voltage reference voltage, and the event detection module
6 determines the gap by determining a period of time while the knee voltage comparator
7 and the zero voltage comparator signal are high but the reference voltage comparator
8 signal is low.

1 9. The power converter of claim 2, wherein the event detection module
2 further detects at the switching frequency at least one selected from the group consisting
3 of the sensed voltage falling lower than the reference voltage, the sensed voltage falling
4 lower than the knee voltage, the sensed voltage falling lower than a zero voltage
5 reference voltage, the sensed voltage rising higher than the zero voltage reference
6 voltage, a rising edge of the pulse signal, a falling edge of the pulse signal, system
7 resonance, and transformer reset time.

1 10. A switch controller for controlling on-times and off-times of a switch that
2 electrically couples or decouples a load to or from a power source in a power converter,

3 the switch controller comprising:

4 an event detection module for generating a digital error signal, the digital
5 error signal being generated at a switching frequency of the switch
6 and indicating a voltage delivered to the load in a first switching
7 cycle of the switch in relation to a reference voltage to be delivered
8 to the load; and

9 a pulse generator coupled to the event detection module for generating a
10 pulse signal that determines the on-time and off-time of the switch
11 for a second switching cycle subsequent to the first switching cycle
12 based upon the digital error signal.

1 11. The switch controller of claim 10, wherein the power converter is a
2 primary side sensing flyback power converter and includes a transformer coupled
3 between the switch and the load and having a primary winding coupled to the switch, a
4 secondary winding coupled to the load, and an auxiliary winding coupled to the switch
5 controller, the switch controller determining:

6 a knee voltage timing, the knee voltage timing indicating the timing when
7 a sensed voltage of the auxiliary winding equals a knee voltage at
8 which a current through the secondary winding of the transformer
9 falls to substantially zero; and

10 a reference voltage timing, the reference voltage timing indicating the
11 timing when the sensed voltage of the auxiliary winding equals the

12 reference voltage.

1 12. The switch controller of claim 11, wherein the event detection module:
2 determines a gap quantifying a difference between the knee voltage
3 timing and the reference voltage timing; and
4 subtracts the gap from a predetermined sample time offset to generate the
5 digital error signal, the sample time offset corresponding to a
6 predetermined time difference between a sampling timing of the
7 sensed voltage and the knee voltage timing.

1 13. The switch controller of claim 12, wherein the knee voltage is lower than
2 the reference voltage by a forward voltage drop of a diode coupled between the
3 secondary winding and the load as reflected on the auxiliary winding, the forward voltage
4 drop corresponding to an amount of current that flows through the diode during the
5 sampling time offset.

1 14. The switch controller of claim 12, wherein the pulse generator generates
2 the pulse signal to decrease the on-time of the switch in the second switching cycle when
3 the digital error signal has a positive value and to increase the on-time of the switch in the
4 second switching cycle when the digital error signal has a negative value.

1 15. The switch controller of claim 12, wherein the pulse generates the pulse
2 signal to maintain the on-time of the switch in the second switching cycle to be same as

3 the on-time of the switch in the first switching cycle when the digital error signal has a
4 value of zero.

1 16. The switch controller of claim 12, further comprising:

2 a knee voltage comparator comparing the sensed voltage to the knee
3 voltage to generate a knee voltage comparator signal that is high
4 when the sensed voltage is higher than the knee voltage and low
5 when the sensed voltage is lower than the knee voltage, the event
6 detection module determining the knee voltage timing by
7 determining a transition timing of the knee voltage comparator
8 signal from high to low; and
9 a reference voltage comparator comparing the sensed voltage to the
10 reference voltage to generate a reference voltage comparator signal
11 that is high when the sensed voltage is higher than the reference
12 voltage and low when the sensed voltage is lower than the
13 reference voltage, the event detection module determining the
14 reference voltage timing by determining a transition timing of the
15 reference voltage comparator signal from high to low.

1 17. The switch controller of claim 16, further comprising a zero voltage
2 comparator comparing the sensed voltage to a zero voltage reference voltage to generate
3 a zero voltage comparator signal that is high when the sensed voltage is higher than the
4 zero voltage reference voltage and low when the sensed voltage is lower than the zero

5 voltage reference voltage, the event detection module determining the gap by determining
6 a period of time while the knee voltage comparator and the zero voltage comparator
7 signal are high but the reference voltage comparator signal is low.

1 18. The switch controller of claim 11, wherein the event detection module
2 further detects at the switching frequency at least one selected from the group consisting
3 of the sensed voltage falling lower than the reference voltage, the sensed voltage falling
4 lower than the knee voltage, the sensed voltage falling lower than a zero voltage
5 reference voltage, the sensed voltage rising higher than the zero voltage reference
6 voltage, a rising edge of the pulse signal, a falling edge of the pulse signal, system
7 resonance, and transformer reset time.

1 19. A method for controlling on-times and off-times of a switch that
2 electrically couples or decouples a load to or from a power source in a power converter,
3 the method comprising:

4 generating a digital error signal at a switching frequency of the switch, the
5 digital error signal indicating a voltage delivered to the load in a
6 first switching cycle of the switch in relation to a reference voltage
7 to be delivered to the load; and

8 generating a pulse signal that determines the on-time and off-time of the
9 switch for a second switching cycle subsequent to the first
10 switching cycle based upon the digital error signal.

1 20. The method of claim 19, wherein the power converter is a primary side
2 sensing flyback power converter and includes a transformer coupled between the switch
3 and the load and having a primary winding coupled to the switch, a secondary winding
4 coupled to the load, and an auxiliary winding coupled to the switch controller, the step of
5 generating a digital error signal including:

6 determining a knee voltage timing, the knee voltage timing indicating the
7 timing when a sensed voltage of the auxiliary winding equals a
8 knee voltage at which a current through the secondary winding
9 falls to substantially zero; and

10 determining a reference voltage timing, the reference voltage timing
11 indicating the timing when the sensed voltage of the auxiliary
12 winding equals the reference voltage.

1 21. The method of claim 20, wherein the step of generating a digital error
2 signal further includes:

3 determining a gap quantifying a difference between the knee voltage
4 timing and the reference voltage timing; and
5 subtracting the gap from a predetermined sample time offset to generate
6 the digital error signal, the sample time offset corresponding to a
7 predetermined time difference between a sampling timing of the
8 sensed voltage and the knee voltage timing.

1 22. The method of claim 21, wherein the knee voltage is lower than the
2 reference voltage by a forward voltage drop of a diode coupled between the secondary
3 winding and the load as reflected on the auxiliary winding, the forward voltage drop
4 corresponding to an amount of current that flows through the diode during the sampling
5 time offset.

1 23. The method of claim 21, wherein the step of generating the pulse signal
2 includes:
3 determining the sign of the digital error signal;
4 responsive to determining that the digital error signal has a positive value,
5 decreasing the on-time of the switch in the second switching cycle;
6 responsive to determining that the digital error signal has a negative value,
7 increasing the on-time of the switch in the second switching cycle.

1 24. The method of claim 21, wherein the step of generating the pulse signal
2 includes:
3 determining the sign of the digital error signal;
4 responsive to determining that the digital error signal has a value of zero,
5 maintaining the on-time of the switch in the second switching
6 cycle to be same as the on-time of the switch in the first switching
7 cycle.

1 25. The method of claim 21, wherein:
2 the step of determining the knee voltage timing includes:

3 comparing the sensed voltage to the knee voltage to generate a
4 knee voltage comparator signal that is high when the
5 sensed voltage is higher than the knee voltage and low
6 when the sensed voltage is lower than the knee voltage; and
7 determining the knee voltage timing by determining a transition
8 timing of the knee voltage comparator signal from high to
9 low, and

10 the step of determining the reference voltage timing includes:

11 comparing the sensed voltage to the reference voltage to generate a
12 reference voltage comparator signal that is high when the
13 sensed voltage is higher than the reference voltage and low
14 when the sensed voltage is lower than the reference
15 voltage; and
16 determining the reference voltage timing by determining a
17 transition timing of the reference voltage comparator signal
18 from high to low.

1 26. The method of claim 25, wherein:

2 the step of generating a digital error signal further includes determining a
3 zero voltage timing by comparing the sensed voltage to a zero
4 voltage reference voltage to generate a zero voltage comparator
5 signal that is high when the sensed voltage is higher than the zero

6 voltage reference voltage and low when the sensed voltage is lower
7 than the zero voltage reference voltage, and
8 the step of determining the gap includes determining a period of time
9 while the knee voltage comparator and the zero voltage comparator
10 signal are high but the reference voltage comparator signal is low.

1 27. A power converter comprising:
2 switching means that electrically couples or decouples a load to or from a
3 power source; and
4 switch controller means coupled to the switching means for controlling
5 on-times and off-times of the switching means, the switch
6 controller means including:
7 means for generating a digital error signal, the digital error signal
8 being generated at a switching frequency of the switching
9 means and indicating a voltage delivered to the load in a
10 first switching cycle of the switching means in relation to a
11 reference voltage to be delivered to the load; and
12 means for generating a pulse signal that determines the on-time
13 and off-time of the switching means for a second switching
14 cycle subsequent to the first switching cycle based upon the
15 digital error signal.

1 28. The power converter of claim 27, wherein the power converter is a

primary side sensing flyback power converter and includes a transformer coupled between the switching means and the load and having a primary winding coupled to the switching means, a secondary winding coupled to the load, and an auxiliary winding coupled to the switch controller means, the switch controller means determining:

- a knee voltage timing, the knee voltage timing indicating the timing when a sensed voltage of the auxiliary winding equals a knee voltage at which a current through the secondary winding falls to substantially zero; and
- a reference voltage timing, the reference voltage timing indicating the timing when the sensed voltage of the auxiliary winding equals the reference voltage.

29. The power converter of claim 28, wherein the means for generating a digital error signal includes:

- means for determining a gap quantifying a difference between the knee voltage timing and the reference voltage timing; and
- means for subtracting the gap from a predetermined sample time offset, the sample time offset corresponding to a predetermined time difference between a sampling timing of the sensed voltage and the knee voltage timing.

30. A switch controller for controlling on-times and off-times of a switch that electrically couples or decouples a load to or from a power source in a power converter,

3 the switch controller comprising:

4 means for generating a digital error signal, the digital error signal being
5 generated at a switching frequency of the switch and indicating a
6 voltage delivered to the load in a first switching cycle of the switch
7 in relation to a reference voltage to be delivered to the load; and
8 means for generating a pulse signal that determines the on-time and off-
9 time of the switch for a second switching cycle subsequent to the
10 first switching cycle based upon the digital error signal.

1 31. The switch controller of claim 30, wherein the power converter is a
2 primary side sensing flyback power converter and includes a transformer coupled
3 between the switch and the load and having a primary winding coupled to the switch, a
4 secondary winding coupled to the load, and an auxiliary winding coupled to the switch
5 controller, the switch controller determining:

6 a knee voltage timing, the knee voltage timing indicating the timing when
7 a sensed voltage of the auxiliary winding equals a knee voltage at
8 which a current through the secondary winding falls to
9 substantially zero; and

10 a reference voltage timing, the reference voltage timing indicating the
11 timing when the sensed voltage of the auxiliary winding equals the
12 reference voltage.

1 32. The switch controller of claim 31, wherein the means for generating a

2 digital error signal includes:

3 means for determining a gap quantifying a difference between the knee

4 voltage timing and the reference voltage timing; and

5 means for subtracting the gap from a predetermined sample time offset,

6 the sample time offset corresponding to a predetermined time

7 difference between a sampling timing of the sensed voltage and the

8 knee voltage timing.